Deep-Sea Research, 1978, Vol. 25, pp. 107 to 117. Pergamon Press. Printed in Great Britain

NOTE

Influence of the Southern Atlantic Central Water on the distribution of salinity and oxygen in the northeast tropical Atlantic Ocean

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(*Received* 6 *August* 1975; *in revised form* 27 *April* 1976; *accepted* 2 *September* 1976)

Abstract—Two main features of the Southern Atlantic Central Water allow its extention to be followed in the northern hemisphere: a salinity minimum located on $\sigma_t = 26.8$ and an oxygen minimum. The salinity minimum has been associated with the coastal upwelling undercurrent off the northwestern coast of Africa but it is not an exclusive feature of this undercurrent south of Cap Blanc. The lowest values of the oxygen minimum are observed in summer in the centre of the Guinea Dome.

INTRODUCTION

THERE IS NO evident relationship *a priori* between the double oxygen minimum observed in the Guinea Dome and the undercurrent flowing northwards in the northwestern African upwelling system. However, the hydrological features of the upper oxygen minimum of the Guinea Dome and those of the compensation undercurrent are similar and show the influence of the Southern Atlantic Central Water (S.A.C.W.) in these two systems.

The double oxygen minimum of the Guinea Dome has been observed by VOITURIEZ and DANDONNEAU (1974). In accordance with the conclusions of BUBNOV (1972) in the Angola region, they suggested that the upper minimum originates from upwelling off the Mauritanian coast. They also showed that this upper oxygen minimum is most pronounced in the central area of the dome where the primary production is very high.

Some authors have recently associated a salinity minimum observed between 200 and 300 m on the slope of the continental shelf of the northwest coast of Africa with a poleward undercurrent associated with the coastal upwelling. TOMCZAK (1972) has observed this salinity minimum associated with a temperature inversion between 20 and 28°N, and HUGHES and BARTON (1974) studied the area between Cap Vert and Cabo Bojador. FRAGA (1973, 1974) has shown that this undercurrent transports South Atlantic Central Waters richer in nutrients than the North Atlantic Central Waters (N.A.C.W.). However, according to TOMCZAK (1972) the extent of the undercurrent is small (10 to 30 km normal to the coast), but HERBLAND, LE BORGNE and VOITURIEZ (1973) have observed, at the latitude of Nouakchott, the salinity minimum associated with a temperature inversion at 100 nautical miles† from the continental shelf. Therefore it may be questioned whether the salinity minimum is an exclusive feature of the undercurrent. To answer this question, the study of the southern part of the CINECA‡ area is interesting because of the seasonal variations of the coastal upwelling and of the corresponding undercurrent. The comparison of the obser-

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† 1 nautical mile = 1.853 km.

‡ CINECA—Co-operative Investigations of the Northern part of the Eastern Central Atlantic.

vations made south of Cap Blanc during the 1973 CINECA Multiship Survey cruises in February (upwelling season) and in August (season without upwelling) give some information about this problem. In this paper we have used the data of the following cruises (Figs. 1 and 2): CINECA Multiship Survey Cruises of the R.V. *Capricorne* in February 1973 and of the R.V. *Thalassa* in August 1973; the 'Dôme de Guinée' cruise of the R.V. *Capricorne* in August 1973.

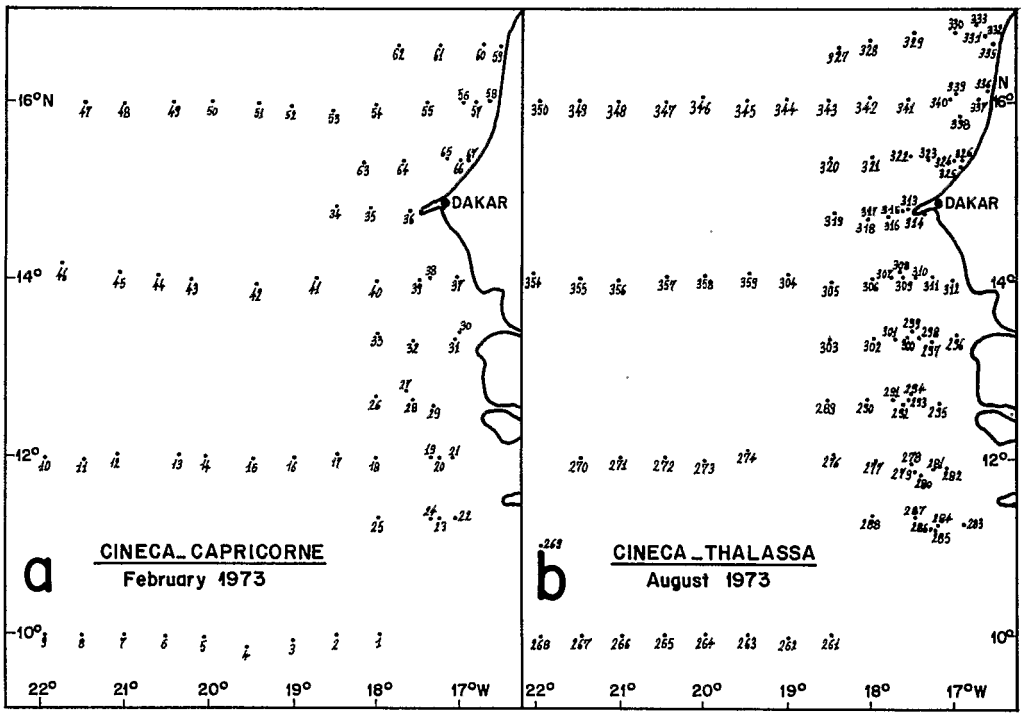

Fig. 1. CINECA Multiship Surveys. (a) R.V. *Capricorne* cruise February 1973; (b) R.V. *Thalassa* cruise August 1973.

RESULTS

1 *Characterization of the S.A.C.W.*

The *T–S* curves of the R.V. *Capricorne* and of the R.V. *Thalassa* cruises show a break around $\sigma_t = 26.8$ (Fig. 3). This break corresponds to a salinity minimum and, often, to a temperature inversion. That property has been used to characterize the poleward undercurrent associated with the coastal upwelling (TOMCZAK, 1972; FRAGA, 1973, 1974; HUGHES and BARTON, 1974). From the south to the north the *T–S* curves shift towards higher salinities but keep this salinity minimum which separates two different water masses (Fig. 4). The upper water mass between approximately 11 and 15°C corresponds to the S.A.C.W., as is shown on Fig. 4 by comparing the southernmost stations (Sta. 9, Sta. 10) with the S.A.C.W., while the lower water mass which diverges from the S.A.C.W. corresponds to the influence of the N.A.C.W.

This suggests that the upper water mass, which is almost typical S.A.C.W. at 10°N, moves

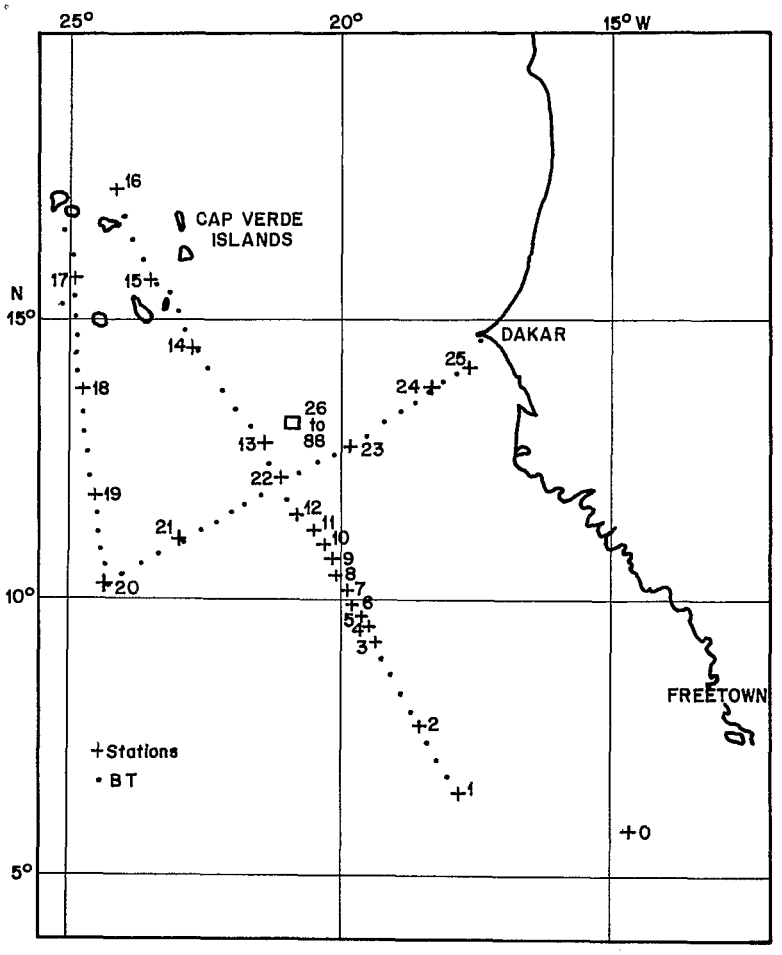

Fig. 2. 'Dôme de Guinée' cruise of the R.V. *Capricorne* in August, 1973.

northwards while the lower water mass which is not yet typical South Atlantic Central Water at 10°N comes from the north and moves southwards.

The vertical distribution of oxygen also allows a distinction between these two water masses. We can see on the T–O_2 curves (Fig. 5) that there are two oxygen minima: the upper one is in the upper water mass (S.A.C.W.) and the deeper one is in the lower water mass (N.A.C.W.). These two oxygen minima are separated by a maximum slightly above the salinity minimum which separates the two water masses. The association of the upper oxygen minimum with the S.A.C.W. is illustrated in Fig. 6 by Stas. 17 and 18 of the 'Dôme de Guinée' cruise. At Sta. 18 where the influence of the S.A.C.W. is strong there is a well-marked oxygen minimum in the upper water mass, while at Sta. 17 (150 nautical miles north of Sta. 18), where the influence of the S.A.C.W. is much less pronounced, the oxygen minimum disappears.

The peculiar structure of the T–S and T–O_2 curves permits the S.A.C.W. to be traced in the northern hemisphere. The upper oxygen minimum is particularly useful to characterize these waters when the salinity minimum does not appear because of a discontinuous sampling.

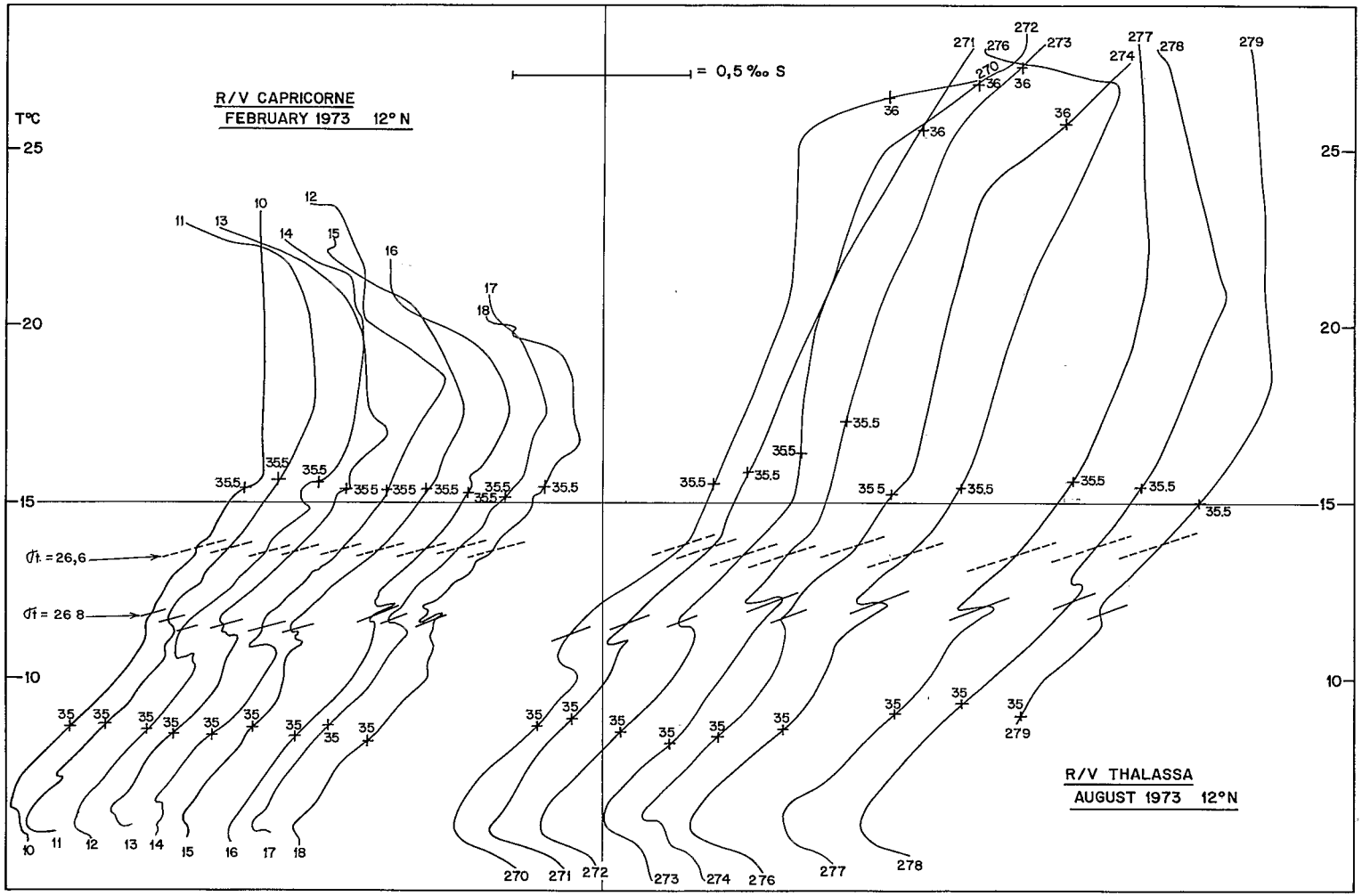

Fig. 3. *T–S* curves on the transect 12°N during the CINECA Multiships Surveys in February 1973 (left) and in August 1973 (right).

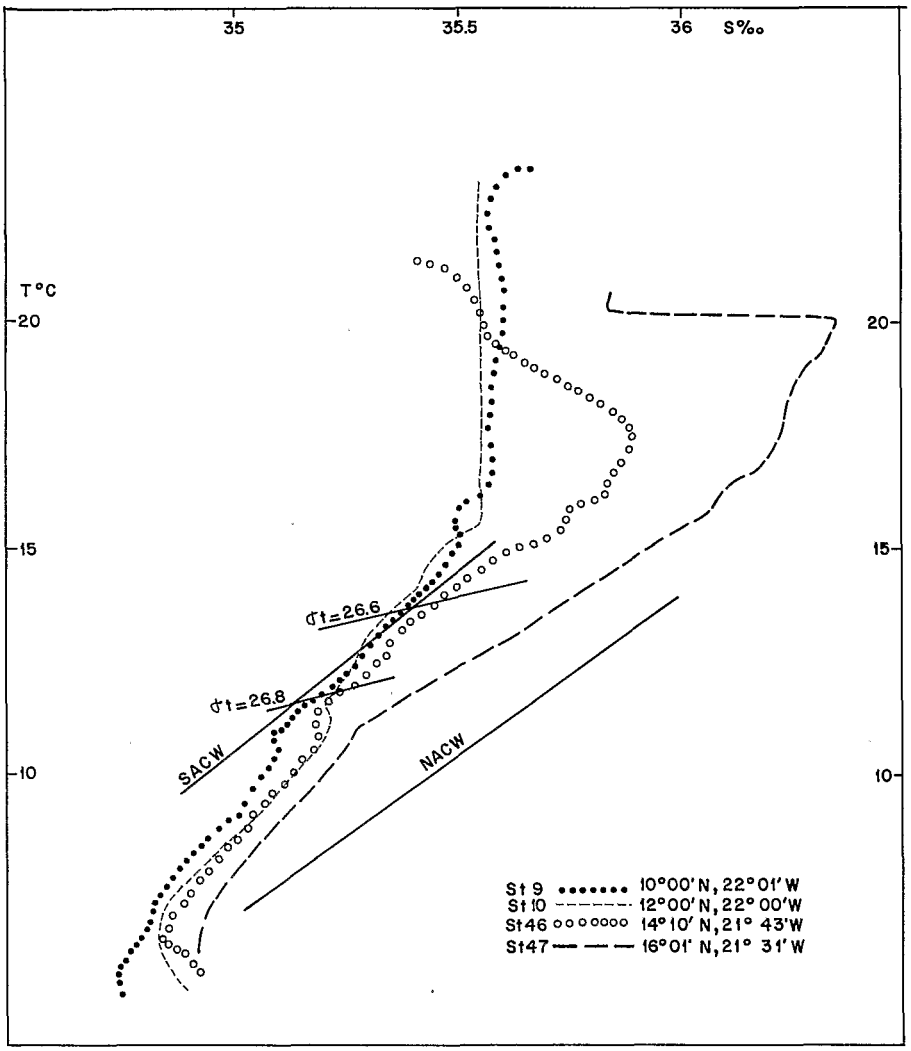

Fig. 4. *T–S* curves of the CINECA Multiships Surveys of the R.V. *Capricorne* in February 1973: Sta. 9 (10°00'N, 22°01'W), Sta. 10 (12°00'N, 22°00'W), Sta. 46 (14°10'N, 21°43'W), Sta. 47 (16°01'N, 21°31'W). S.A.C.W.—South Atlantic Central Water; N.A.C.W.—North Atlantic Central Water.

2 *Extension of the S.A.C.W.*

The situations were quite different in February and in August 1973 as may be shown by the surface distributions of temperature and salinity (Fig. 7). In February a strong upwelling occurred in the coastal region between 12°N and 16°N while in August there was no evidence of upwelling in the area. In February the surface salinity was everywhere less than 35.8‰ while in August the salinity was higher than 36‰ in the northwestern part of the zone. This contrast between the two seasons is strongly reduced at the level of the S.A.C.W.

The salinity minimum on $\sigma_t = 26.8$. The salinity minimum appears during the two seasons (Fig. 3) as well in the coastal area as in the open sea (Fig. 8). It has been observed even at

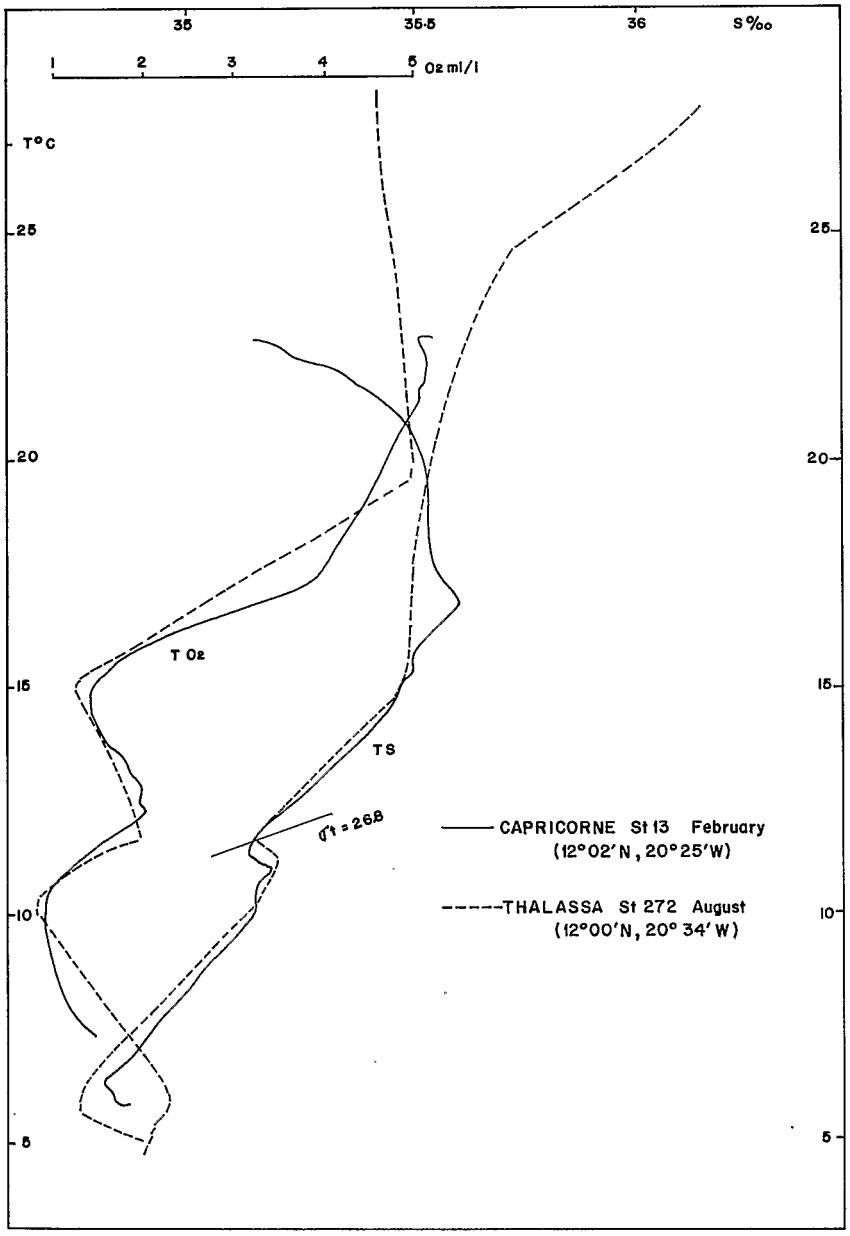

Fig. 5. *T–S* and *T*–O_2 curves of the CINECA Multiships Surveys at approximately the same point in February (Sta. 13 of the R.V. *Capricorne*) and in August (Sta. 272 of the R.V. *Thalassa*).

Sta. 18 of the 'Dôme de Guinée' cruise, 450 nautical miles from the coast (Fig. 6). It is, therefore, a general feature of this region and does not depend on the occurrence of either the coastal upwelling or the poleward compensation undercurrent. FRAGA (1973, 1974) has already noticed that the S.A.C.W. reached Cap Blanc in all seasons and that it was carried

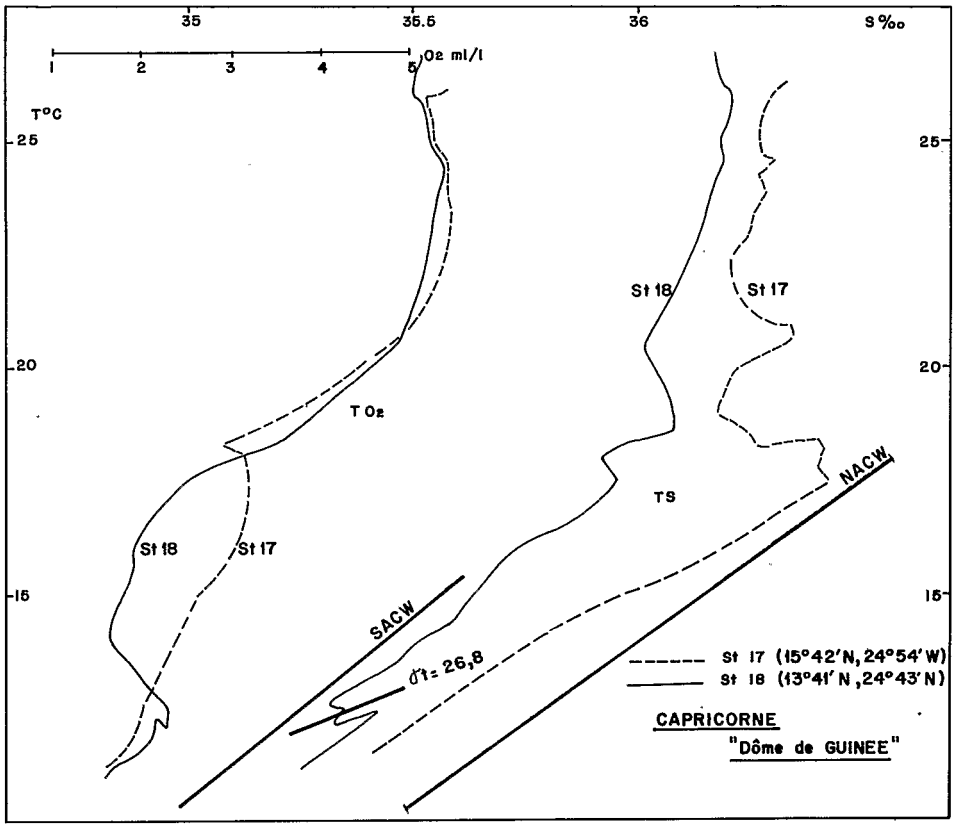

Fig. 6. T–S and T–O_2 curves of the Stas. 17 and 18 of the 'Dôme de Guinée' cruise (R.V. *Capricorne* August 1973).

north of Cap Blanc, where the upwelling is permanent, by the undercurrent, and as was observed by HUGHES and BARTON (1974). Thus two regions can be distinguished (1) south of Cap Blanc where the salinity minimum on $\sigma_t = 26.8$ is a general permanent feature not depending on the undercurrent and associated with the northward motion of the S.A.C.W.; (2) north of Cap Blanc where the salinity minimum is probably a characteristic property of the undercurrent carrying the S.A.C.W. northwards along the coast.

However, the influence of the South Atlantic Central Water is not exactly the same in February and in August. In Figs. 3 and 4 it may be considered that the core of the S.A.C.W. is approximately on $\sigma_t = 26.6$. The distribution of the salinity on this surface shows that the extention of the S.A.C.W. to the northwest is greater in February than in August due to its transport in the upwelled waters in February but not in August (Fig. 9).

The oxygen minimum of the S.A.C.W. The extension of the upper oxygen minimum follows that of the S.A.C.W. but dissolved oxygen content of the water is not a conservative property and its distribution does not necessarily coincide with the salinity distribution. However, this oxygen minimum is present everywhere in the region except where salinity exceeds 35.8‰ on $\sigma_t = 26.6$ in the northwestern part of the zone where the influence of the S.A.C.W. vanishes (Fig. 9).

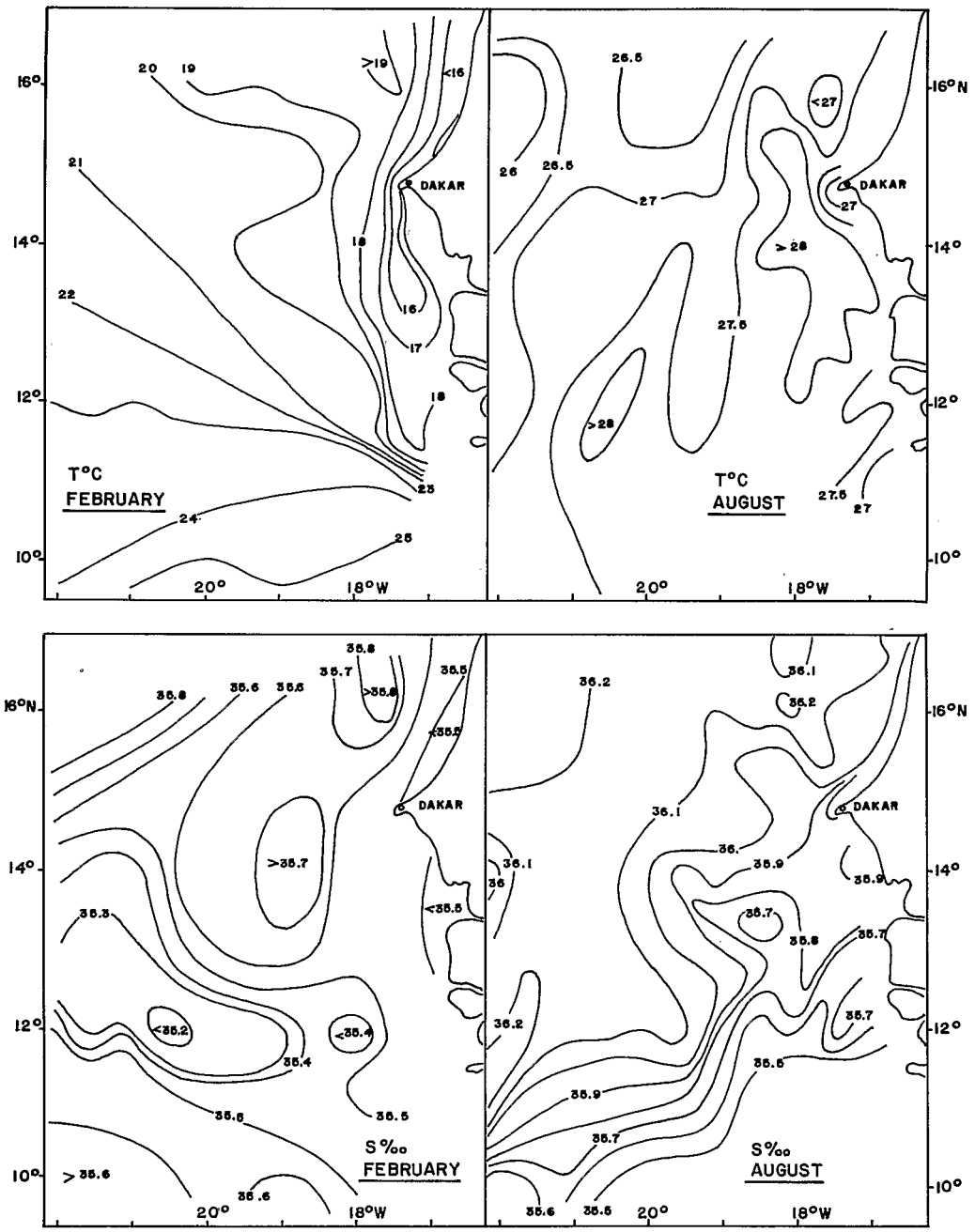

Fig. 7. Surface distribution of temperature and salinity in February and August 1973.

The lowest values of the upper oxygen minimum ($<0.7\,ml\,l^{-1}$) were observed in August between 12–14°N and 20–22°W. This is the central part of the Guinea Dome described by VOITURIEZ and DANDONNEAU (1974), precisely where the primary production ($1\,g\,C\,m^{-2}\,day^{-1}$) and the planktonic biomasses are maximum.

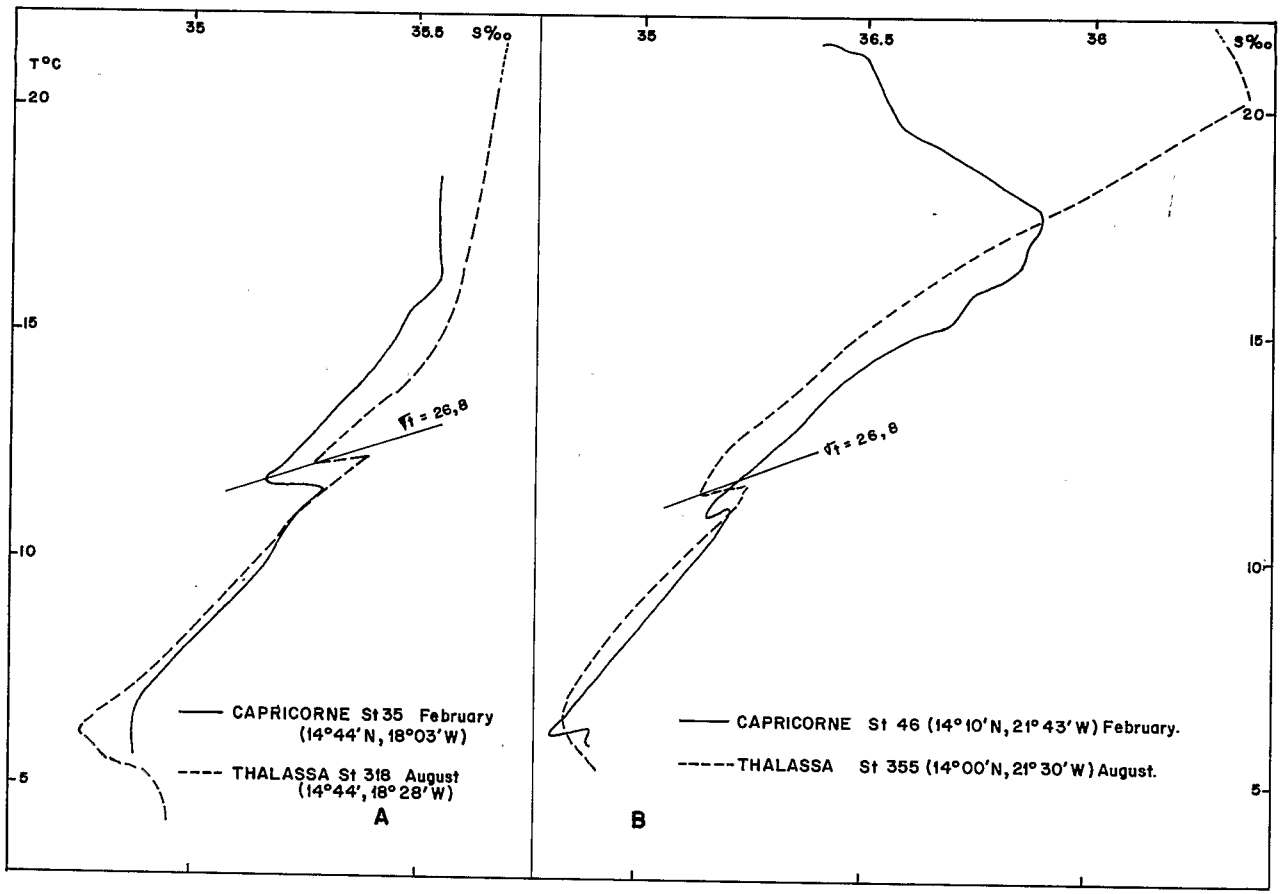

Fig. 8. *T–S* curves in February and August 1973. A—Inshore stations; B—offshore stations.

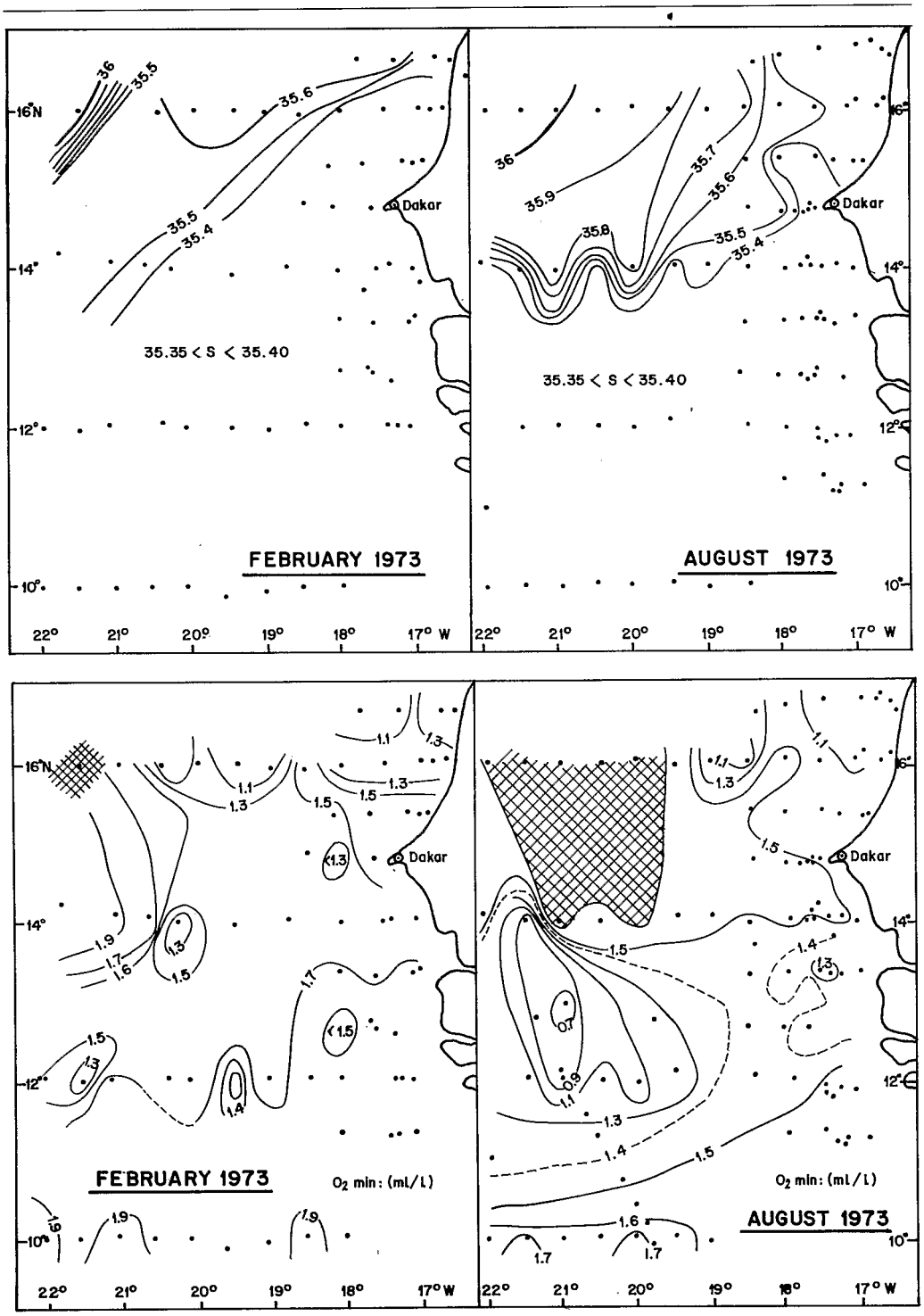

Fig. 9. A—Distribution of salinity on $\sigma_t = 26.6$ in August and February 1973; B—distribution of the upper oxygen minimum in August and February 1973.

Surprisingly in February during the upwelling season, the values of the oxygen minimum are similar to those of August except in the area of the Guinea Dome, which does not exist in winter (MAZEIKA, 1968). It is suggested that the high production and the very low motions observed in the centre of the Dome in August (VOITURIEZ and DANDONNEAU, 1974) lower the oxygen minimum of the S.A.C.W. more than the coastal upwelling.

CONCLUSION

In the northern hemisphere the South Atlantic Central Water is a water mass separated from a deeper one by a salinity minimum and a temperature inversion. An oxygen minimum is associated with it. South of Cap Blanc the salinity minimum is a general permanent feature depending neither on coastal upwelling nor the compensation undercurrent. North of Cap Blanc it seems to be a characteristic property of the undercurrent carrying the South Atlantic Central Waters northwards. The oxygen minimum layer of the South Atlantic Central Water is particularly depleted in August in the central part of the Guinea Dome.

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